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(54) [Title of the Invention] FILM FORMING METHOD AND FILM FORMING APPARATUS

(57) [Abstract]

[Object] To allow a high-quality micro-particle film to be stably formed with a high rate by heating and evaporating a vaporable raw material efficiently and stably even in a case

of using a vaporable raw material with a high melting point and a boiling point.

[Solving Means] Provided is a micro-particle film forming method of forming a film by transferring micro-particles, which evaporate from an evaporating source 13 arranged in a micro-particles chamber 1, to a film forming chamber 2 via a transfer pipe 3 having an opening portion 17 above the evaporating source 13, and by thus depositing the micro-particles, which are ejected from a nozzle connected to the other opening portion 4 of the transfer pipe 3, on a substrate 8 placed opposite to the nozzle. The micro-particle film forming method is characterized in that the evaporating source 13 is heated and kept at a temperature not higher than, and close to, its melting point by a high-frequency induction heating coil 6, and in that the evaporating source 13 is rapidly heated and evaporated by an arc electrode 5.

[Scope of Claims]

[Claim 1] A film forming method of forming a film by transferring micro-particles evaporating from an evaporating source arranged in a micro-particles chamber, together with a gas introduced into the micro-particles chamber, to a film forming chamber via a transfer pipe having an opening portion above the evaporating source, and by thus depositing the micro-particles, which are ejected from a nozzle connected to the other opening portion of the transfer pipe, on a substrate placed opposite to the nozzle in the film forming chamber, characterized in that

the evaporating source is heated and kept at a temperature not higher than, and close to, its melting point by primary heating means, and

the evaporating source is rapidly heated and evaporated by secondary heating means.

[Claim 2] The film forming method as recited in claim 1, characterized in that high-frequency induction heating means is used as the primary heating means.

[Claim 3] The film forming method as recited in any one of claims 1 and 2, characterized in that relative positions of the secondary heating means and the evaporating source are controlled.

[Claim 4] The film forming method as recited in claim 3, characterized in that, while the secondary heating means and the evaporating source are turned relative to each other, the secondary heating means and the evaporating source are moved relative to each other, respectively, in arbitrary radius directions of the turning circle.

[Claim 5] The film forming method as recited in any one of claims 1 to 4, characterized in that arc plasma heating means is used as the secondary heating means.

[Claim 6] The film forming method as recited in any one of claims 1 to 4, characterized in that laser irradiation heating means is used as the secondary heating means.

[Claim 7] The film forming method as recited in any one of claims 1 to 4, characterized in that arc plasma irradiation means and laser irradiation heating means are used as the secondary heating means.

[Claim 8] A film forming apparatus that includes: a micro-particles producing chamber provided with an evaporating source and an opening portion of a transfer pipe above the evaporating source; and a film forming chamber provided with a nozzle connected to the other opening portion of the transfer pipe and a stage onto which to fix a substrate placed opposite to the nozzle, and that forms a film by transferring micro-particles evaporating from the evaporating source, together with a gas introduced into the micro-particles chamber in the transfer pipe, and by thus depositing the micro-particles, which are ejected from the nozzle, on the substrate,

the film forming apparatus characterized by comprising:

primary heating means for heating and keeping the evaporating source at a temperature not higher than, and close to, its melting point; and

secondary heating means for rapidly heating and evaporating the evaporating material.

[Claim 9] The film forming apparatus as recited in claim 8, characterized in that the primary heating means is high-frequency induction heating means.

[Claim 10] The film forming apparatus as recited in any one of claims 8 and 9, characterized in that relative positions of the secondary heating means and the

evaporating source can be controlled.

[Claim 11] The film forming apparatus as recited in claim 10, characterized in that, while the secondary heating means and the evaporating source are turned relative to each other, the secondary heating means and the evaporating source can be moved relative to each other, respectively, in arbitrary radius directions of the turning circle.

[Claim 12] The film forming apparatus as recited in any one of claims 8 to 11, characterized in that the secondary heating means is arc plasma heating means.

[Claim 13] The film forming apparatus as recited in any one of claims 8 to 11, characterized in that the secondary heating means is laser irradiation heating means.

[Claim 14] The film forming apparatus as recited in any one of claims 8 to 11, characterized in that the secondary heating means is the arc plasma irradiation means and the laser irradiation heating means.

[Claim 15] A film forming method of forming a film by depositing a material evaporating from an evaporating source on a substrate placed in a film forming chamber, characterized by comprising:

a first heating step of heating the evaporating source at a temperature not higher than a temperature at which the material melts; and

a second heating step of further heating the evaporating source up to a temperature not lower than a temperature at which the material evaporates.

[Claim 16] The film forming method as recited in claim 15, characterized in that, in the first heating step, the evaporating source is heated at a temperature not higher than, and close to, the temperature at which the material melts.

[Claim 17] The film forming method as recited in any one of claims 15 and 16, characterized in that, in the first heating step, the evaporating source is heated at a temperature not higher than a temperature at which the material melts, and not lower than a temperature which is 50 degrees K (Kelvin) lower than the temperature at which the material melts.

[Claim 18] The film forming method as recited in any one of claims 15 to 17,

characterized in that, in the second heating step, the evaporating source is heated in an area narrower than an area which is heated in the first heating step.

[Claim 19] The film forming method as recited in any one of claims 15 to 18, characterized in that, in the second heating step, the evaporating source is heated from a surface from which the material evaporates.

[Claim 20] A film forming apparatus for forming a film by depositing a material evaporating from an evaporating source on a substrate placed in a film forming chamber, characterized by comprising:

first heating means for heating the evaporating source at a temperature not higher than a temperature at which the material melts;

second heating means for further heating the evaporating source up to a temperature not lower than a temperature at which the material evaporates.

[Detailed Description of the Invention]

[0001]

[Technical Field to which the Invention Pertains] The present invention relates to a gas deposition apparatus for forming a particle film, a fine particle film, a micro-particle film or a green compact on a substrate.

[0002]

[Prior Art] Once floated in a gas, micro-particles each with a particle size of 0.1 μm or less is aerosolized and their free fall velocity due to the gravity becomes so small that the micro-particles are transferred easily along with a flow of the gas. These phenomena are hardly influenced by the density of micro-particles, no matter how different the density is among materials such as metals and chemical compounds. It has been reported that a micro-particle film can be formed by the use of this property (Transactions, 90th Seminar on New Ceramics, New Ceramics Forum). Specifically, a substance is vaporized in a micro-particles producing chamber, and the vaporized substance is transferred together with a He gas to a film forming chamber via a transfer pipe. In the film forming chamber, the micro-particles aggregating in the air are ejected from a nozzle of the transfer pipe to

the top surface of a substrate at a very high speed, and thus are adhered to the top surface of the substrate. Thereby, the micro-particle film is formed. Accordingly, the gas deposition method imposes no specific restriction on a material for a film to be formed on a substrate and allows a micro-particle film to be formed of a metal, an inorganic substance, an organic chemical compound, or the like.

[0003] By contrast, in the case of a thick film method of baking a printing paste, which is generally used as the film forming method, and a thin film method such as vacuum deposition and sputtering, a material for a film to be formed on a substrate is limited to metal oxides and the like.

[0004]

[Problem to be Solved by the Invention] However, a conventional gas deposition apparatus needs high energy to evaporate a material with a high melting point and a high boiling point since the gas deposition apparatus heats and melts a bulk material for micro-particles using high-frequency heating or the like. Moreover, the gas deposition apparatus needs equipment capable of supplying a heating system with a large electric power. In addition, although the conventional gas deposition apparatus heats the transfer pipe or the nozzle, the micro particles produced in the micro-particles producing chamber cool or aggregate before transferred by the use of a transfer gas and ejected from the nozzle. For this reason, the gas deposition method has a problem that an adhesion of the micro particles to the substrate is smaller while produced than while deposited to form a film. As a result, the gas deposition method has a problem that it is difficult to stably form a high-quality film with a high rate by using a material with a high melting point and a boiling point.

[0005] In addition, a method of evaporating a material for micro-particles by combining several heating methods is also used. However, this method has a problem that it is difficult to evaporate the material for micro-particles efficiently, because the heat given to the material diffuses due to convection in the material even though the material is heated once melts.

[0006] A chief object of the present invention is to provide a film forming method and a film forming apparatus which are capable of solving the problem with film formation using a material with a high melting point and the high boiling point, of evaporating the material efficiently, and of realizing stable formation of a high-quality film with a high rate.

[0007]

[Means for Solving the Problem] A film forming method according to the present invention is a film forming method of forming a film by transferring micro-particles evaporating from an evaporating source arranged in a micro-particles chamber, together with a gas introduced into the micro-particles chamber, to a film forming chamber via a transfer pipe having an opening portion above the evaporating source, and by thus depositing the micro-particles, which are ejected from a nozzle connected to the other opening portion of the transfer pipe, on a substrate placed opposite to the nozzle in the film forming chamber. The film forming method is characterized in that: the evaporating source is heated and kept at a temperature not higher than, and close to, its melting point by primary heating means; and the evaporating source is rapidly heated and evaporated by secondary heating means.

[0008] In addition, a film forming method according to the present invention is a film forming apparatus including: a micro-particles producing chamber provided with an evaporating source and an opening portion of a transfer pipe above the evaporating source; and a film forming chamber provided with a nozzle connected to the other opening portion of the transfer pipe and a stage onto which to fix a substrate placed opposite to the nozzle, the film forming apparatus for forming a film by transferring micro-particles evaporating from the evaporating source, together with a gas introduced into the micro-particles chamber, in the transfer pipe, and by thus depositing the micro-particles, which are ejected from the nozzle, on the substrate. The film forming method is characterized by including: primary heating means for heating and keeping the evaporating source at a temperature not higher than, and close to, its melting point; and

secondary heating means for rapidly heating and evaporating the evaporating source.

[0009] In the case of the present invention, the evaporating source is heated and kept at the temperature not higher than, and close to, its melting point by the primary heating means, and the evaporating source is rapidly heated by the secondary heating means. This makes it possible to stably heat and evaporate a material with a high melting point and a high boiling point efficiently, and to stably form a high-quality film with a high rate.

[0010] Additional characteristics of the film forming method and the film forming apparatus according to the present invention include "high-frequency induction heating means is used as the primary heating means," "relative positions of the secondary heating means and the evaporating source are controlled," "while the secondary heating means and the evaporating source are turned relative to each other, the secondary heating means and the evaporating source are moved relative to each other, respectively, in arbitrary radius directions of the turning circle," "arc plasma heating means is used as the secondary heating means," "laser irradiation heating means is used as the secondary heating means," and "arc plasma irradiation means and laser irradiation heating means are used as the secondary heating means."

[0011] Moreover, a film forming method according to the present invention is a film forming method of forming a film by depositing a material evaporating from an evaporating source on a substrate placed in a film forming chamber. The film forming method is characterized by including: a first heating step of heating the evaporating source at a temperature not higher than a temperature at which the material melts; and a second heating step of further heating the evaporating source up to a temperature not lower than a temperature at which the material evaporates.

[0012] Additional characteristics of the film forming method according to the present invention include "in the first heating step, the evaporating source is heated at a temperature not higher than, and close to, a temperature at which the material melts," " in the first heating step, the evaporating source is heated at a temperature not higher than the temperature at which the material melts, and not lower than a temperature which is 50

degrees K (Kelvin) lower than the temperature at which the material melts," "in the second heating step, the evaporating source is heated in an area narrower than an area which is heated in the first heating step," and "in the second heating step, the evaporating source is heated from a surface from which the material evaporates."

[0013] Furthermore, a film forming apparatus according to the present invention is a film forming apparatus for forming a film by depositing a material evaporating from an evaporating source on a substrate placed in a film forming chamber. The film forming apparatus is characterized by including: first heating means for heating the evaporating source at a temperature not higher than a temperature at which the material melts; second heating means for further heating the evaporating source up to a temperature not lower than a temperature at which the material evaporates.

[0014] In this respect, a particle film, a fine particle film, and a micro-particle film can be obtained as a film to be formed in the case of the present invention. The film forming method and the film forming apparatus according to the present invention are capable of being appropriately used for forming a film of micro-particles each with a particle size of not larger than 0.1 μm in particular.

[0015]

[Best Mode for Carrying out the Invention] Fig. 1 is a schematic diagram of a gas deposition apparatus, which shows an embodiment of the present invention.

[0016] An opening 17 of a transfer pipe 3 is arranged opposite to an evaporating source unit in a micro-particles producing chamber 1. The evaporating source unit is configured of: a stage 18 on which to fix a micro-particle raw material (evaporating source) 13; a high-frequency induction heating coil 6 which is primary heating means; and an arc electrode 5 for secondary heating.

[0017] An opening 4 of the transfer pipe 3, to which a nozzle (not illustrated) is attached, is arranged in a film forming chamber 2. In the film forming chamber 2, a stage 7 on which to fix a substrate 8 is arranged in a position opposite to the nozzle. The stage can be moved to an arbitrary position.

[0018] The micro-particle raw material 13 arranged on the stage 18 evaporates by heating. Evaporated micro-particles are turned into a flow of micro-particles 14 by an air flow which is caused through introducing an inert gas into the micro-particles producing chamber 1 via a valve 9 attached to the micro-particles producing chamber 1, and through simultaneously reducing the pressure in the film forming chamber 2 by operating a vacuum pump 10 via a valve 11 attached to the film forming chamber 2. Thus, the micro-particles are transferred to the film forming chamber 2 from the opening 17 of the transfer pipe 3, and are ejected 16 from the nozzle (not illustrated) arranged in the opening 4 at a high speed, hence formed into a micro-particle film on the top surface of the substrate 8.

[0019] Fig. 2 is a magnified view showing an embodiment of the evaporating source unit in the gas deposition apparatus shown in Fig. 1. The evaporating source unit is configured of: the stage 18 on which to fix the micro-particle raw material 13; the high-frequency induction heating coil 6, which is arranged in the surroundings of the stage 18, and which is the primary heating means; and a laser heating mechanism or an arc heating mechanism which is the secondary heating means 5. Incidentally, Fig. 2 is a diagram showing the high-frequency induction heating coil 6 whose parts are cut away.

[0020] A high-frequency power supply, which is not illustrated, is attached to the high-frequency induction heating coil 6. In addition, a temperature sensor, which is not illustrated, is arranged in the stage 18. The temperature of high-frequency induction heating is controlled by feeding back a result of measurement by the temperature sensor, which is not illustrated. Incidentally, the stage 18 is capable of moving upward and downward 23.

[0021] While the micro-particle raw material 13 is heated and kept at a temperature not higher than, and close to, its melting point by primary heating through high-frequency induction heating means, the micro-particle raw material 13 is rapidly heated through arc discharge 19 and evaporated. Thereby, micro-particles are produced. A flow of micro-particles 20 transfers the micro-particles from the opening 17 of the transfer pipe 3

to the film forming chamber with an air flow which is caused by lowering the pressure in the film forming chamber more than that in the micro-particles producing chamber. Thus, the micro-particles are ejected from the nozzle at a high speed, hence form a micro-particle film on the top surface of the substrate. Incidentally, the secondary heating can be performed by the use of laser irradiation heating instead of arc discharge heating.

[0022] Fig. 3 is a magnified view showing another embodiment of the evaporating source unit in the gas deposition apparatus shown in Fig. 1. The evaporating source unit is configured of: the stage 18 on which to fix the micro-particle raw material 13; the high-frequency induction heating coil 6 which is arranged in the surroundings of the stage 18, and which is the primary heating means; and the laser heating mechanism or the arc heating mechanism which is the secondary heating means 5. Incidentally, Fig. 3 is a diagram showing the high-frequency induction heating coil 6 whose parts are cut away.

[0023] The high-frequency power supply, which is not illustrated, is attached to the high-frequency induction heating coil 6. In addition, the temperature sensor, which is not illustrated, is arranged in the stage 18. The temperature of high-frequency induction heating is controlled by feeding back a result of measurement by the temperature sensor, which is not illustrated. Incidentally, the stage 18 is capable of turning 22, and of moving upward and downward 23. Furthermore, the arc heating mechanism and the laser heating mechanism, which are the secondary heating means 5, are capable of scanning 21 in the radius direction of the stage 18.

[0024] While the micro-particle raw material 13 is heated and kept at a temperature not higher than, and close to, its melting point by primary heating through the high-frequency induction heating, the micro-particle raw material 13 is rapidly heated through arc discharge 19 and evaporated. Thereby, micro-particles are produced. At this time, by turning the stage 18 and simultaneously scanning the arc heating mechanism 5 in the radius direction of the stage 18, an arbitrary area of the surface of the micro-particle raw material 13 can be heated rapidly. A flow of micro-particles 20 transfers the

micro-particles from the opening 17 of the transfer pipe 3 to the film forming chamber with an air flow caused by lowering the pressure in the film forming chamber more than that in the micro-particles producing chamber. Thus, the micro-particles are ejected from the nozzle at a high speed, hence form a micro-particle film on the top surface of the substrate. Incidentally, the secondary heating can be performed by the use of laser irradiation heating instead of arc discharge heating.

[0025]

[Examples] Specific descriptions will be provided below for examples of the present invention.

[0026] (Example 1) In this example, a micro-particle film was formed by the use of the apparatus with the configurations shown in Figs. 1 and 2.

[0027] A stainless steel pipe with an inner diameter of 1.6 mm was used for the transfer pipe 3. Alumina-coated tungsten with a diameter of 25 mm and a thickness of 8 mm was used for the stage 18.

[0028] The high-frequency induction heating coil, which was the primary heating means 6, was coiled 6 times, and was shaped like a bowl. A lower diameter of the high-frequency induction heating coil was smaller than an upper diameter thereof. The lowermost coil was 20 mm in inner diameter, and the uppermost coil was 35 mm in diameter. A 50-kHz high-frequency power supply of a vacuum-tube oscillation type with a 5-kW output was used for the high-frequency power supply.

[0029] Arc discharge heating was adopted for the secondary high-frequency heating means 5. Tungsten was used for the electrode, and a 20V-80A power supply was used.

[0030] The nozzle was 0.1 mm in diameter, and was 35 mm in length. The distance between the opening 17 of the micro-particles transfer pipe 3 and an evaporating source crucible was 70 mm. In addition, helium gas was introduced into the micro-particles producing chamber 1 and the film forming chamber 2. The atmospheric pressure in the micro-particles producing chamber 1 was increased, and the atmospheric pressure in the film forming chamber 2 was decreased by the vacuum pump. Thereby, the difference in

inner pressure between the micro-particles producing chamber 1 and the film forming chamber 2 was set at 2.1 atm.

[0031] 30 grams of zirconium was placed in the evaporating source crucible. A current was flown to the high-frequency coil 6. On the basis of a result of measurement by the temperature sensor in the stage 18, the current to be flown to the high-frequency coil 6 was controlled. Thereby, zirconium was heated up to approximately 1800°C which was lower than, and close to, its melting point of 1852°C. Subsequently, the arc electrode was fixed to a position which was approximately 5 mm above the surface of zirconium, and arc discharge heating was performed. Thus, zirconium was evaporated. While the secondary heating was being performed, the current to be flown to the high-frequency coil 6 was also controlled on the basis of a result of measurement by the temperature sensor in the stage 18.

[0032] In the present example, a glass substrate was placed on the top surface of the stage 7 in the film forming chamber 2, and thus the film formation was performed for 20 minutes. Thereby, zirconium was heated and evaporated efficiently and stably, and the rate of film formation was as fast as 0.75 μm/sec. A high-quality film was formed stably with the high rate.

[0033] (Example 2) In this example, a micro-particle film was formed by the use of the apparatus with the configurations shown in Fig. 1 and 3.

[0034] A stainless steel pipe with an inner diameter of 1.6 mm was used for the transfer pipe 3. Alumina-coated tungsten with a diameter of 25mm was used for the stage 18.

[0035] The high-frequency induction heating coil, which was the primary heating means 6, was coiled 6 times, and was shaped like a bowl. A lower diameter of the high-frequency induction heating coil was smaller than an upper diameter thereof. The lowermost coil was 20 mm in inner diameter, and the uppermost coil was 35 mm in diameter. A 50-kHz high-frequency power supply of a vacuum-tube oscillation type with a 5-kW output was used for the high-frequency power supply.

[0036] Arc discharge heating was adopted for the secondary high-frequency heating

means. Tungsten was used for the electrode, and a 20V-80A power supply was used.

[0037] The nozzle was 0.1 mm in diameter, and was 35 mm in length. The distance between the opening 17 of the micro-particles transferring pipe 3 and an evaporating source crucible was 70 mm. In addition, helium gas was introduced into the micro-particles producing chamber 1 and the film forming chamber 2. The atmospheric pressure in the micro-particles producing chamber 1 was increased, and the atmospheric pressure in the film forming chamber 2 was decreased by the use of the vacuum pump. Thereby, the difference in inner pressure between the micro-particles producing chamber 1 and the film forming chamber 2 was set at 2.1 atm.

[0038] 30 grams of zirconium was placed in the evaporating source crucible. A current was flown to the high-frequency coil 6. On the basis of a result of measurement by the temperature sensor in the stage 18, the current to be flown to the high-frequency coil 6 was controlled. Thereby, zirconium was heated up to approximately 1800°C which was lower than, and close to, its melting point of 1852°C. Subsequently, the arc electrode was fixed to a position which was approximately 5 mm above the surface of zirconium, and arc discharge heating was performed. Thus, zirconium was evaporated. While the secondary heating was being performed, the current to be flown to the high-frequency coil 6 was also controlled on the basis of a result of measurement by the temperature sensor in the stage 18. At this time, an arbitrary area in the surface of zirconium was rapidly heated by turning the stage 18 and simultaneously scanning the arc electrode 5 in a radius direction of the stage.

[0039] In the present example, a glass substrate was placed on the top surface of the stage 7 in the film forming chamber 2, and thus the film formation was performed for 20 minutes. Thereby, zirconium was heated and evaporated more efficiently and more stably in the present example than in Example 1, and the rate of film formation was as fast as 0.98 μm/sec. A high-quality film was formed stably with the high rate.

[0040] (Comparative Example) In this comparative example, a micro-particle film was formed by the use of a conventional gas deposition apparatus as shown in Fig. 4.

[0041] A film forming chamber 102 is vacuumed by a vacuum pump 114 connected to the film forming chamber 102 via a valve 115. This causes the difference in pressure between the micro-particles producing chamber 101 and the film forming chamber 102. A high-frequency induction heating coil 111 is arranged to the surroundings of a crucible 103. A substance 104 to be evaporated is contained in the crucible 103. In the micro-particle producing chamber 101, aerosolized metal micro-particles produced by resistance heating are transferred into the film forming chamber 102 with the pressure difference in an atmosphere of an inert gas introduced via a valve, and are ejected into the film forming chamber 2 rapidly from a nozzle 108. Thereby, the gas deposition apparatus forms a micro-particle film and green compact aggregates on a substrate 107. In addition, by closing a valve 110, the transfer of micro-particles is stopped.

[0042] A stainless steel pipe with an inner diameter of 1.6 mm was used for a transfer pipe 105. The high-frequency induction heating coil 111 was coiled 6 times, and was shaped like a bowl. A lower diameter of the high-frequency induction heating coil 111 was smaller than an upper diameter thereof. The lowermost coil was 20 mm in diameter, and the uppermost coil was 35 mm in diameter. A 50-kHz high-frequency power supply of a vacuum-tube oscillation type with a 5-kW output was used for the high-frequency power supply.

[0043] The nozzle was 0.1 mm in diameter, and was 35 mm in length. The distance between the opening of the micro-particles transferring pipe and the evaporating source crucible was 70 mm. In addition, helium gas was introduced into the micro-particles producing chamber 101 and the film forming chamber 102. The atmospheric pressure in the micro-particles producing chamber 101 was increased, and the atmospheric pressure in the film forming chamber 102 was decreased by the use of the vacuum pump. Thereby, the difference in inner pressure between the micro-particles producing chamber 101 and the film forming chamber 102 was set at 2.1 atm.

[0044] While the lids of the opening portions in the discharging mechanism and the ejection mechanism were being closed, 30 grams of zirconium was placed in the

evaporating source crucible, and was heated up to approximately 2500 °C and evaporated by high-frequency heating. A glass substrate was placed on the top surface of the stage in the film forming chamber, and thus the film formation was performed for 20 minutes. The rate of film formation was 0.43 μm/sec.

[0045]

[Effects of the Invention] In the case of the present invention, a raw material is heated and kept at a temperature not higher than, and close to, its melting point by the primary heating means (primary heating step), followed by rapid heating by the secondary heating means (secondary heating step). Thereby, even if a raw material with a high melting point and a high boiling point is used, the raw material can be heated and evaporated efficiently and stably. This makes it possible to form a high-quality film, such as a micro-particle film, stably and with a high rate.

[0046] A raw material is heated and kept at a temperature not higher than, and close to, its melting point by the primary heating means (primary heating step), followed by rapid heating by the secondary heating means (secondary heating step), and particularly the stage on which to fix the raw material and the secondary heating mechanism are moved to their respective arbitrary positions so that an arbitrary area in the surface of the raw material is heated and evaporated. This makes it possible to heat and evaporate a raw material with a high melting point and a high boiling point more efficiently and stably, and to thus form a very high-quality film, such as a micro-particle film, with a very high rate.

[Brief Description of the Drawings]

Fig. 1 is a schematic diagram showing an embodiment of a gas deposition apparatus according to the present invention.

Fig. 2 is a magnified view showing an evaporating source unit in the gas deposition apparatus used for Example 1 of the present invention.

Fig. 3 is a magnified view showing an evaporating source unit of a gas deposition apparatus used for Example 2 of the present invention.

Fig. 4 is a diagram showing a conventional gas deposition apparatus used for a comparative example.

[Explanation of Reference Numerals]

1 micro-particles producing chamber

2 film forming chamber

3 transfer pipe

4 opening

5 arc electrode

6 high-frequency induction heating coil

7 stage

8 substrate

9 valve

10 vacuum pump

11 valve

12 vacuum gauge

13 micro-particle raw material

14, 15, 16 flow of micro-particles

17 opening

18 stage

19 discharge

20 flow of micro-particles

21 direction in which arc electrode is moved

22 direction in which stage is turned

23 direction in which stage is moved

101 micro-particles producing chamber

102 film forming chamber

103 evaporating source crucible

104 evaporating source substance

105 micro-particles transferring pipe

106 flow of micro-particles

107 substrate

108 nozzle

109 micro-particles

110 valve

111 high-frequency induction heating coil

112 high-frequency power supply

113 valve

114 vacuum pump

115 valve

116 pressure gauge

FIG. 1

FIG. 2

FIG. 3

FIG. 4